

## DRAFT 4/97

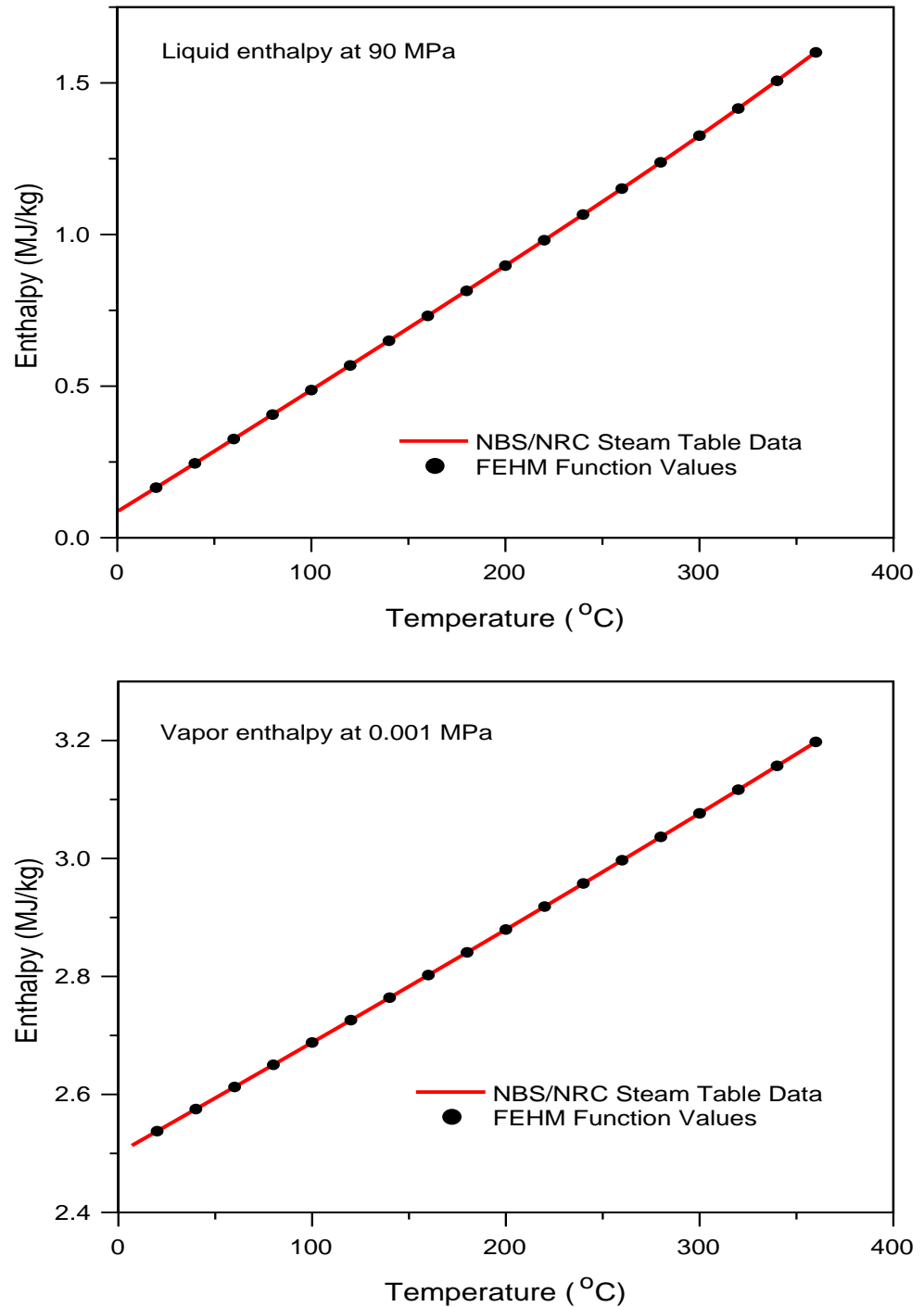
### 4.1 Testing of Thermodynamic Functions

#### 4.1.1 Enthalpy

These tests verify that the FEHM enthalpy functions provide accurate values of enthalpy as illustrated in Figure 20. The results, compared numerically to the values used to generate the enthalpy functions (found in files *thermo.steam\_table\_data.liq* and *thermo.steam\_table\_data.vap*), are given in Table 42. The maximum absolute error for liquid enthalpy was less than 0.003 MJ/kg, and the percent error was less than 0.2%. The maximum absolute error for vapor enthalpy was 0.0001 MJ/kg, and the percent error was less than 0.004%. These results meet the acceptance criteria for this test suite developed in Chapter III, "Verification and Validation Plan."

Table 42. Results of tests of thermodynamic functions			
V&V test	Maximum error	Maximum % error	RMS error
Enthalpy			
Liquid	0.2100e-02	0.1319	0.1732e-04
Vapor	0.9012e-04	0.3129e-02	0.3128e-05
Density			
Liquid	1.522	0.2482	0.2018e-04
Vapor	0.2550e-01	0.5793e-01	0.6295e-04
Compressibility			
Liquid	0.2160e-02	16.00	0.5182e-02
Vapor	1.287	0.1297	0.4074e-03
Viscosity			
Liquid	0.3224e-05	0.5244	0.9222e-04
Vapor	0.3650e-07	0.1601	0.1687e-03
Saturation pressure and temperature			
Pressure	0.2575e-01	0.3000	0.4687e-03
Temperature	1.100	0.4000	0.5943e-03

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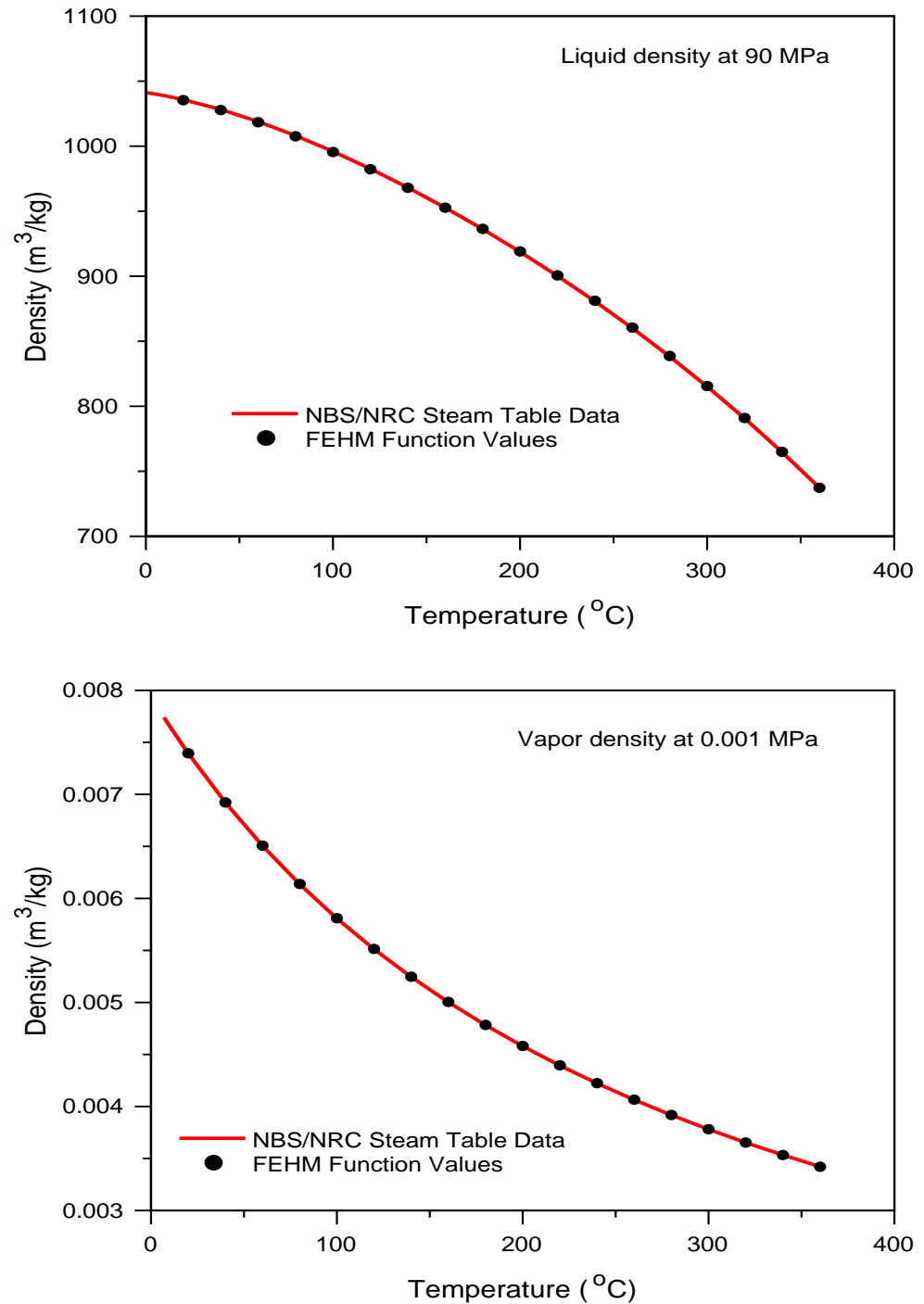
**Figure 20. Comparison of FEHM enthalpies to the *NBS/NRC Steam Tables* data.**

#### 4.1.2 Density

These tests verify that the FEHM density functions provide accurate values of density as illustrated in Figure 21. The results, compared numerically to the values used to generate the density functions (found in files *thermo.steam\_table\_data.liq* and *thermo.steam\_table\_data.vap*), are

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given in Table 42. The maximum absolute error for liquid density was less than  $1.6 \text{ m}^3/\text{kg}$ , and the percent error was less than 0.3%. The maximum absolute error for vapor density was  $0.026 \text{ m}^3/\text{kg}$ , and the percent error was less than 0.06%. These results meet the acceptance criteria for this test suite developed in Chapter III.

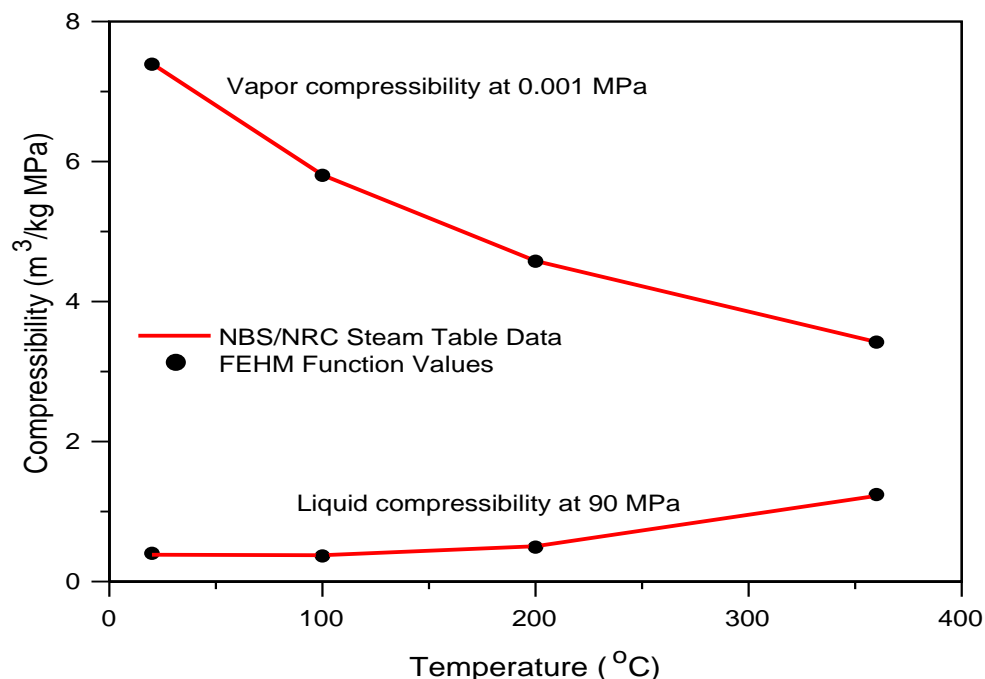


**Figure 21. Comparison of FEHM densities to the *NBS/NRC Steam Tables* data.**

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### 4.1.3 Compressibility (derivative of density with respect to pressure)

These tests verify that the FEHM compressibility functions provide accurate values of compressibility as illustrated in Figure 22. The results, compared numerically to the values used to generate the compressibility functions (found in files *thermo.compress\_data.liq* and *thermo.compress\_data.vap*), are given in Table 42. The maximum absolute error for liquid compressibility was less than  $0.0022 \text{ MPa}^{-1}$ , and the percent error was less than 16%. The maximum absolute error for vapor compressibility was  $1.3 \text{ MPa}^{-1}$ , and the percent error was less than 0.2%. These results for vapor compressibility meet the acceptance criteria for this test suite developed in Chapter III. The liquid compressibility had a maximum error greater than the acceptance criteria but the root-mean-square (RMS) error was within acceptable limits. Although the absolute maximum error of liquid compressibility is outside the acceptance criteria, it is important to note that this calculated value of liquid compressibility is never used in the governing equations. This fact is shown best in the accurate solution of the fully saturated Theis problem (see Section 4.4), which would be most sensitive to liquid-compressibility deviations.



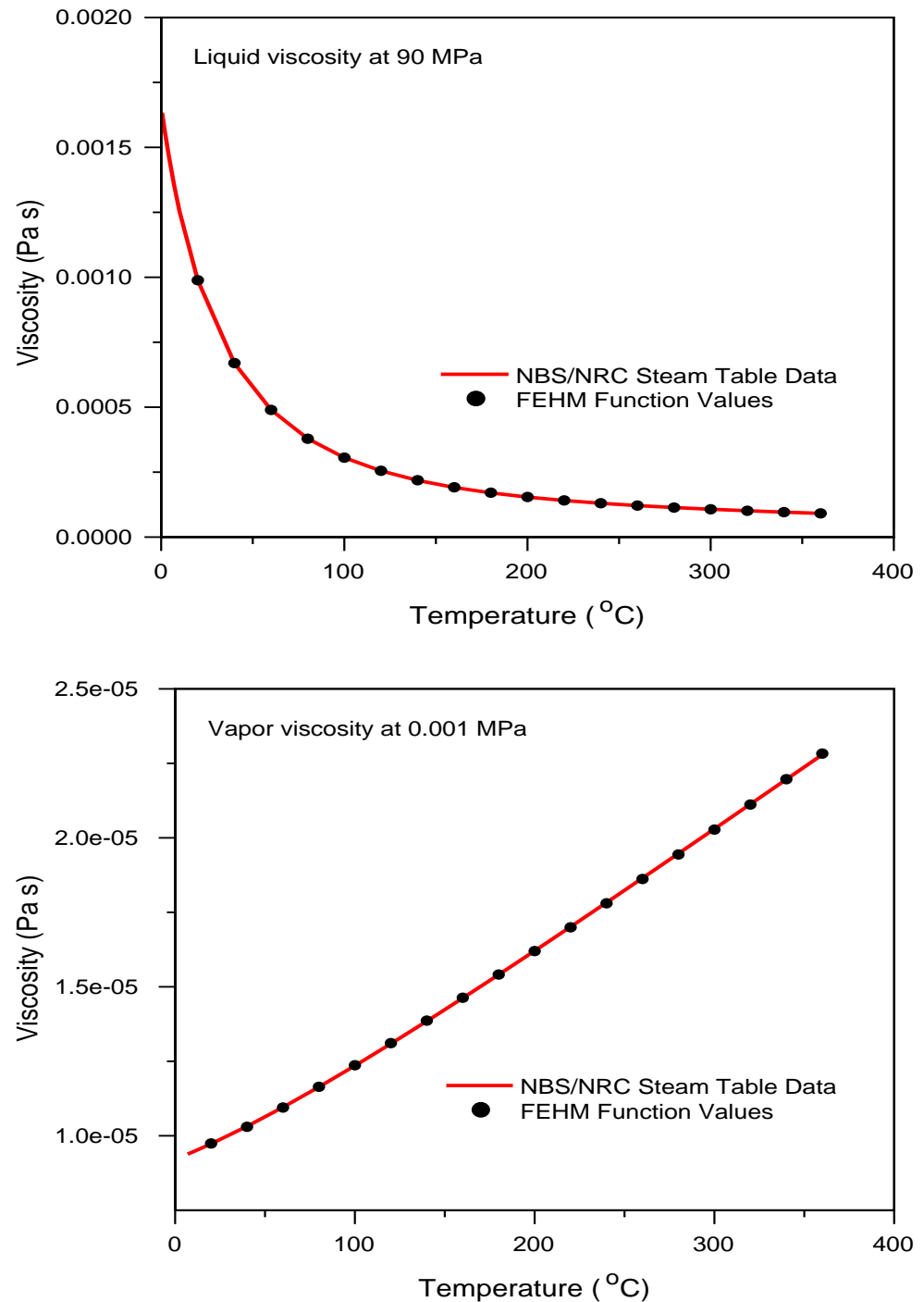
**Figure 22. Comparison of FEHM compressibilities to the NBS/NRC Steam Tables data.**

### 4.1.4 Viscosity

These tests verify that the FEHM viscosity functions provide accurate values of viscosity as illustrated in Figure 23. The results, compared numerically to the values used to generate the enthalpy functions (found in files *thermo.steam\_table\_data.liq* and *thermo.steam\_table\_data.vap*), are given in Table 42. The maximum absolute error for liquid viscosity was less than  $3.2 \times 10^{-6} \text{ Pa}\cdot\text{s}$ , and the percent error was less than 0.6%. The

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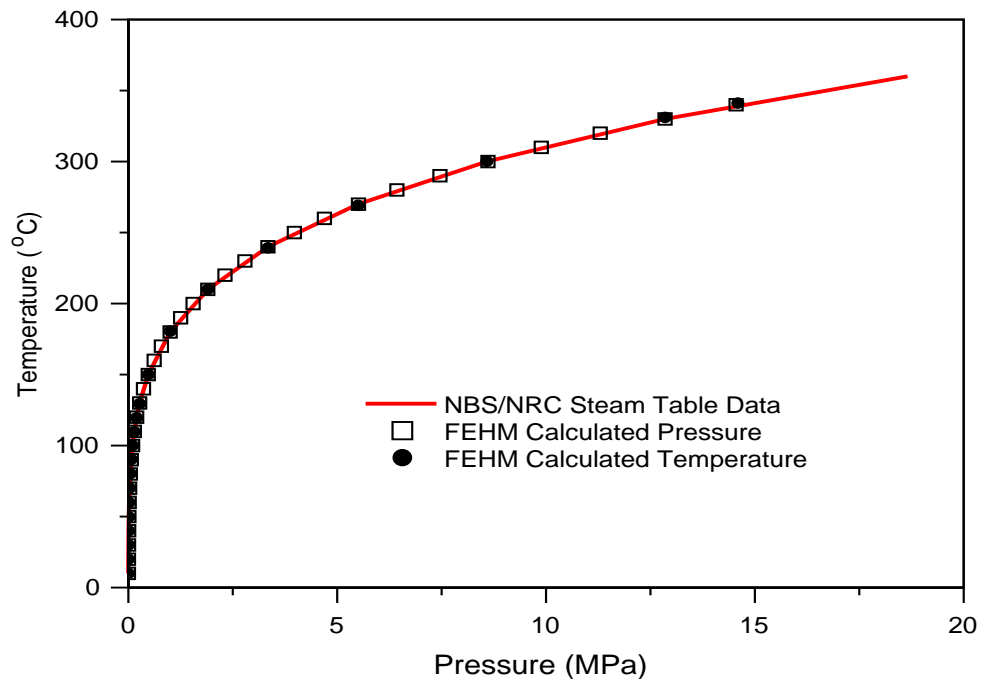
maximum absolute error for vapor viscosity was  $3.65 \times 10^{-8} \text{ Pa}\cdot\text{s}$ , and the percent error was less than 0.2%. These results meet the acceptance criteria for this test suite developed in Chapter III.



**Figure 23. Comparison of FEHM viscosities to the *NBS/NRC Steam Tables* data.**

#### 4.1.5 Saturation pressure and temperature

These tests verify that the FEHM saturation functions provide accurate values of pressure and temperature as illustrated in Figure 24. The results, compared numerically to the values used to generate the saturation functions (found in file *thermo.saturation\_data*), are given in Table 42. The maximum absolute error for saturation pressure was less than 0.03 MPa, and the percent error was less than 0.3%. The maximum absolute error for saturation temperature was 1.1 °C, and the percent error was less than 0.4%. These results meet the acceptance criteria for this test suite developed in Chapter III.



**Figure 24. Comparison of FEHM saturation pressures and temperatures to the *NBS/NRC Steam Tables* data.**